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The Relation of Some Tobacco Viruses to Potato Degeneration.

W. D. VALLEAU and E. M. JOHNSON

During the last twenty years much of the attention of seed potato growers and those studying potato diseases has centered on degenerative diseases with special reference to their commercial control. The method most commonly used in control is that of roguing, or pulling out of the seed plot all plants which appear abnormal. The results are generally beneficial but in certain locations difficulty is encountered in keeping seed stock even relatively free from the degenerative diseases. In other locations this is done rather easily. A knowledge of the cause of this difference may give a basis for a successful program of virus disease elimination from potato varieties.

On the Experiment Station farm at Lexington and on certain farms in the vicinity virus diseases of tobacco are encountered which are not generally found in tobacco fields of the State. While the immediate source of the viruses seems to be weeds, some evidence suggests that originally the viruses were introduced into the weed flora from potatoes.

In this bulletin evidence is presented to show that at least one of these virus diseases of tobacco is caused by a virus commonly present in Irish Cobbler potatoes affected with mosaic, that it appears to be the cause of this mosaic disease, and that certain other viruses of tobacco are capable of causing disease in potatoes and are probably concerned in the potato virus problem. The results obtained by other investigators in cross-inoculations from potatoes to tobacco are discussed, and an attempt is made to correlate them with the results obtained in the present study.

REVIEW OF LITERATURE

The literature on the relation of the virus diseases of the potato to those of tobacco is not extensive, and is not readily interpreted in terms of specific viruses. The work of Quanjer (11)*, in which the grafting method was used, indicated that at least three viruses or virus combinations could be transmitted from potato to tomatoes. These were the common mosaic, Aucuba mosaic, and crinkle. Aucuba mosaic caused no symptoms when transmitted to tobacco, but the virus from inoculated tobacco was passed to potatoes by grafting. As potatoes generally carry a virus which readily passes to tomato, these results are not easily interpreted. Johnson (8) has pointed out that Quanjer's crinkle mosaic is probably the same as Schultz and Folsom's rugose mosaic, and with this view the present writers agree, as the virus combination from rugose mosaic potatoes produces the type of symptoms on tomato pictured by Quanjer (11) when crinkle was transmitted to tomato by grafting (see his pl. 3, fig. 15).

Olitsky and Northrop (9) demonstrated that a virus could be transferred from diseased or apparently healthy potatoes to tobacco and tomatoes where it produced a disease which they thought was "identical with the natural affection in tomatoes and tobacco." It is suggested that they may have been dealing with the healthy-potato virus and not with the true tobacco mosaic virus, as they seemed to believe.

Fernow (3) transferred but one disease from potatoes affected by various mosaic diseases, to other hosts. He designated this virus B.

Blodgett (1) inoculated peppers from several varieties of potatoes and demonstrated that each carried a virus capable of causing a severe disease in peppers. He concluded that the virus concerned was the same as Fernow's virus B and Johnson's mottle. He stated that "only a few plants having this disease have been seen in commercial fields" but gave no proof that in these the disease was caused by the potato virus. E. M. John-

*Numbers in parentheses refer to the list of titles under "Literature Cited," at the end of this Bulletin.

son (5) obtained only faint symptoms on pepper with the healthy-potato virus but obtained symptoms similar to Blodgett's when peppers were inoculated with the spot-necrosis virus mixture to be discussed in the present paper.

Schultz (12) tuber grafted certain apparently healthy potato varieties with each other and with seedlings and found that necrotic streaks developt on certain of the varieties and seedlings. Juice inoculations from such necrotic seedlings to certain apparently healthy seedlings resulted in necrosis of the latter.

The probable universal presence of a virus or viruses in supposedly healthy commercial potatoes was first demonstrated by Johnson (6). He was of the opinion that two and perhaps three viruses are commonly, if not universally, present in standard varieties of potatoes. The diseases produced on tobacco by inoculation from potatoes he called mottle, spot-necrosis, and ringspot, and thought that the two former were perhaps different expressions of the same disease.

Recently two papers appeared by Smith (13) on the comparative effects of a mosaic disease of potatoes on tobacco when transferred by mechanical means and by the insect *Myzus persicae,* and on the increased virulence of the disease in tobacco produced by continued rapid transfers thru tobacco. His findings may be summarized as follows: 1. When the juice of so-called healthy potatoes (varieties President and Arran Victory) was transferred to tobacco no symptoms developt, which indicated to him that they do not carry a virus. 2. When the juice of mosaic potatoes was pricked into healthy tobacco plants a disease developt which he called ringspot. He concluded that it was identical with the ringspot of tobacco commonly found in America. 3. Insect transmission by *M. persicae* from mosaic potatoes to tobacco or from ringspot tobacco to tobacco, resulted in a different disease from that induced by pricking. It is characterized by vein-clearing as the first symptom and by bands of dark green along the veins of the older leaves. It may be transferred from plant to plant of tobacco as a distinct disease. Ringspot, and the insect-transmitted disease,

when passed to apparently healthy potatoes, produced an identical mosaic. 4. Rapid transfer of ringspot from tobacco to tobacco seemed to increase its virulence. The increased virulence persisted if the tobacco disease was transferred to "healthy" potatoes and then to tobacco by the prick method, but was lost if passed to potatoes by insects and then to tobacco by pricking. Altho the evidence suggests a virus mixture, Smith concluded that "It cannot be that the aphis picks up one constituent part of a possible virus complex, because it has been shown already that *M. persicae* can transmit potato mosaic to healthy potatoes unchanged."

James Johnson (8), in his study of rugose mosaic, evidently dealt with a similar disease of potatoes. His results may be summarized as follows: 1. Green Mountain potatoes affected with rugose mosaic, received from Dr. Donald Folsom, in every case yielded on tobacco infection of the spot-necrosis type (a disease evidently identical with Smith's ringspot). 2. Inoculations from apparently healthy potatoes and from potatoes affected with virus diseases, to tobacco, commonly produce at least two and perhaps three diseases in tobacco, which he calls mottle, spot-necrosis, and ringspot. 3. Ringspot and mottle, when transferred from tobacco to potatoes, produce no symptoms. 4. Spot-necrosis, when transferred from tobacco to Bliss Triumph potatoes, produces a severe disease characterized by necrosis and loss of leaves, being similar to the disease described by Smith (13) when potatoes were inoculated with his ringspot virus. 5. The virus which causes spot-necrosis and rugose mosaic in tobacco and potatoes, respectively, can readily be altered so that it produces no symptoms in potatoes and only mottle in tobacco. 6. While consideration was given to the possibility of spot-necrosis being caused by a virus mixture, "it was finally concluded that 'mottle' was only a mild form of spot-necrosis, and both forms were included in one category."

THE PROBLEM

In studies of the virus diseases of tobacco as they occur in Kentucky, the tentative conclusion was reached (15) that certain of them originated in potatoes, spread from them to perennial

weeds, and might then be transmitted from the weeds to tobacco years later by insects. Consequently a more complete study of certain virus diseases of potatoes was undertaken. In the course of this work the same general results have been obtained in cross inoculation studies between mosaic potatoes and tobacco, and between so-called healthy potatoes and tobacco, as were obtained by Smith (13), and Johnson (8). But because of a different method of approach another interpretation seems possible.

THE HEALTHY-POTATO VIRUS

In the present study a virus has been transferred from apparently healthy Irish Cobbler potatoes to tobacco many times. The first transfers from Cobblers to comparatively large Turkish tobacco plants usually produce mild symptoms which are often extremely difficult to detect. Faint chlorotic spots may develop on the rubbed leaves and later faint watered-silk chlorotic patterns may appear in the growing point leaves. Transfers from potatoes to small vigorously growing Turkish tobacco plants have given positive results more consistently. The first symptoms are faint chlorotic spots on the rubbed leaves which may infrequently be followed by small necrotic rings. There is usually no sign of vein-chlorosis or vein-clearing in the growing-point leaves. One or two of the larger leaves may develop mild chlorosis leaving the small veins and tissue immediately adjoining them standing out as darker green areas (Plate 1, A). Later leaves, if growth is rapid, usually develop faint patterns in the form of rings or curved lines well described as watered-silk patterns. Small necrotic ring and line patterns, also, may develop. In subsequent transfers to young Turkish plants the symptoms may become more marked. On the rubbed leaves small necrotic rings about 2 mm. in diameter, with a necrotic dot in the center, are typical (Plate 1, B). These develop in the centers of the faintly chlorotic spots. In later leaves the watered-silk patterns develop either with or without necrotic ring and line patterns (Plate 1, C).

The necrotic ring patterns of the healthy-potato virus have been illustrated by Smith (13) in Plate I, figures 1, 2 and 3,

and by Johnson (6) in Plate 2, B. This is the symptom which both have named ring-spot. It is not the same disease as ringspot of tobacco commonly found in the field in the United States (5) and should not be confused with it in comparative studies of the two (Plate 1, B and D). As the evidence so far obtained in the present investigation seems to indicate that only one virus, the so-called ringspot, is present in apparently healthy potatoes, and as there is another virus disease of tobacco, which also affects potatoes, and is now commonly called ringspot, it would seem better to refer to the virus obtained from healthy potatoes as the healthy-potato virus until convincing evidence is presented that more than one virus is concerned.

Three strains of the healthy-potato virus carried for about two years in the greenhouse in Turkish tobacco, and frequently transferred, usually produced more marked symptoms than result in first transfers from potato. Their virulence appears to have been increased slightly by long habitation in tobacco.

These strains of the healthy-potato virus have been transferred to seedling potato plants* where recognizable symptoms were produced the following tuber generation. The symptoms were faint chlorosis between the larger veins, with deeper green along these veins. Symptoms were usually faint or absent in the newest leaves, but quite easily seen in older leaves. They were the same as those commonly present in apparently healthy Bliss Triumph foliage when grown in the greenhouse. The virus is easily transferred from infected seedling potatoes to tobacco. Positive results were obtained from recently inoculated plants, from tubers of these plants, and from second tuber generation plants. It is of interest to note that the healthy-potato virus, when transferred to tobacco from these seedling potatoes, produces a disease of the more virulent type in the first transfer, in comparison with the less prominent symptoms when inoculations are made directly from naturally infected Cobblers to tobacco. It is this potato virus which, in combination with the true to-

*The seedling potato plants used in these studies were raised from seed kindly furnished by Dr. Fred Krantz, University of Minnesota. The seedlings were grown in the greenhouse and most of the inoculations were made the first generation.

bacco mosaic virus and other viruses, has been found to produce streak in tomatoes, certain of the strains used in the present study having been used in such experiments (16).

The viruses obtained from Irish Cobblers, Bliss Triumph, Green Mountain, and from two unidentified varieties cause the same kind of symptoms in tobacco; but there may be considerable difference in the intensity of symptoms produced.

The healthy-potato virus from a strain of Maine Irish Cobblers produced particularly prominent symptoms, whereas the virus from Maine Green Mountain resulted in mild symptoms when transferred to tobacco. The disease in tobacco produced by the virus from any of the varieties mentioned appears to be identical with Johnson's "ringspot" disease (6). This appears to be the virus universally distributed in so-called healthy potatoes.

VEINBANDING

Veinbanding is a common disease of tobacco in locations where potatoes have been grown frequently. The symptoms are readily recognized in Burley tobacco in the field, the most pronounced being the dark green bands of tissue along the veins of the older light green leaves and the small chlorotic spots in the growing-point leaves. Spread in the field, probably due to insects, is often rapid and occurs at periods when the crop is not being handled by man. Transfers of one strain thru a series of 14 tobacco plants, as well as numerous other transfers thru tobacco and other species (5), leave no doubt that veinbanding is a distinct virus disease not to be confused with any of the other virus diseases under study. On Turkish tobacco plants the first symptoms are prominent vein-chlorosis in the leaves of the growing point (Plate 3, A), followed by a general mild chlorosis with faint mottling resulting from more extensive chlorosis in the vein islets. Then the new leaves, as they are produced, are spotted with small chlorotic spots which gradually increase in size (Plate 2, A and B). There is a distinct tendency for the leaves already present on inoculated plants to droop. Finally, bands of dark green develop along some of the veins of the older leaves (Plate 2.).

When inoculations are made from mottled Cobbler potato plants to relatively large Turkish tobacco plants (in which the healthy-potato virus produces but faint symptoms) the symptoms are usually predominently those of veinbanding with occasionally mild symptoms of spot-necrosis (Plate 2, C). Johnson (8) and Smith (13) have each reported similar mild symptoms in transfers from other varieties of mosaic-affected potatoes to tobacco. Transfers from such tobacco plants to others produced, in several instances, what appears to be pure veinbanding in tobacco and in other instances spot-necrosis. The veinbanding disease when obtained from mosaic potatoes appears identical with that obtained from naturally infected tobacco plants in the field.

In the present studies it was found that the veinbanding virus, when transferred to apparently healthy young Cobbler potato plants, produced typical rugose mosaic. When more mature plants were inoculated a severe necrotic disease usually resulted. Smith obtained somewhat similar results in that insect transmission of his insect-transmitted virus (veinbanding) to potatoes resulted in an intensified mosaic, while mechanical transmission of ring-spot (veinbanding and healthy-potato) produced an intensified mosaic which was sometimes fatal.

The veinbanding virus was transferred to seedling potato plants and a number of plants were grown from the tubers of these. The virus transferred readily from these potatoes to tobacco and resulted in typical veinbanding symptoms (Table I).

Table 1. Inoculations from seedling potatoes infected with veinbanding from tobacco, to tobacco.

Source of Inoculum	Plants Inoculated	Results
	Tobacco	Veinbanding
Potato 2259, veinbanding	2539-40	2
Potato 3750, veinbanding	3815	2
Potato 3750, veinbanding, crushed tubers	4068-9	2
Potato 4325, veinbanding, 2nd generation	4354-5	
	4473-4	
	4708-9	6
Potato 5514, veinbanding, 2nd generation	5567A-9A	3
Potato 5516, veinbanding, 2nd generation	5567-9	3
Potato 5507, veinbanding, 3rd generation	5557-60	4
Potato 5517A, veinbanding, 3rd generation	5561A-3A	3
Potato 5496 1-7, veinbanding, 3rd generation	5658-64	7
Potato 5517A 1-6, veinbanding, 3rd generation	5767-78	12

Successful transfers were made from recently inoculated plants, tubers from these, and second and third tuber generation plants. The veinbanding virus caused a disease of seedling potatoes characterized by nearly normal color, faint mottling, rugoseness, and only slight distortion in leaf shape (Plate 4, A).

The work of Smith (13), when interpreted in terms of the present work, demonstrates that the veinbanding virus (his insect-transmitted disease) may be transmitted by the aphid *Myzus persicae* and can be passed either from tobacco to potatoes, or from mosaic potatoes to potatoes, in both instances producing mosaic.

THE "SPOT-NECROSIS" DISEASE OF TOBACCO

Transfers from mottled Irish Cobbler potatoes to tobacco sometimes result in a disease in which the symptoms are predominently those of veinbanding. This is especially true if relatively large plants are inoculated. When small, rapidly growing Turkish plants are inoculated with mosaic Cobbler juice, spot-necrosis usually results, altho occasionally only the healthy-potato disease develops. The first symptoms of spot-necrosis are chlorotic spots on rubbed leaves. In these spots necrotic rings identical with those produced by the healthy-potato virus sometimes develop. Then vein-chlorosis develops in the upper leaves (Plate 3, A) and is followed in a few days by partial vein-necrosis (Plate 3, B) which frequently results in their death. The growing point may then partially recover, the new leaves taking on symptoms similar to those of veinbanding, except that the chlorotic spots may become necrotic later (Plate 2, C). It appears from these results that the typical early spot-necrosis symptoms develop, in first transfers from potato, when the tobacco plant is in a condition suitable for the optimum development of the healthy-potato virus symptoms (Plates 1, A and 3).

In a study of spot-necrosis in comparison with veinbanding and healthy-potato diseases in tobacco, the former shows similarities to both of the latter. In first transfers from mosaic potatoes to well-developt tobacco plants, the veinbanding symptoms may

predominate. In later transfers to small, vigorously growing tobacco plants, the chlorotic spots and, later, the small necrotic rings so characteristic of the healthy-potato disease usually develop on rubbed leaves. Then vein-chlorosis typical of veinbanding, but more severe, develops in two or three leaves and is followed by necrosis of the veins of these leaves. The growing point then tends to recover, developing symptoms more typical of veinbanding except that the chlorotic spots may eventually become necrotic. Finally, the typical banding of the veins may develop on the older leaves as the plants advance in age (Plate 2, C). This mixture of symptoms suggested that two viruses were concerned in the spot-necrosis disease of tobacco.

Proof of the mixed-virus theory of spot-necrosis was obtained in several ways. Passage of the healthy-potato virus alone from potatoes containing the spot-necrosis complex was strikingly demonstrated in inoculations made from etiolated sprouts of Cobbler potatoes grown in a dark cellar, as compared with transfers from sprouts from halves of the same tubers grown in the greenhouse. In one series 10 tubers were used, one-half of each being grown in the greenhouse and the other half planted in a shallow layer of soil and placed in a cellar from which light was excluded. Inoculations were made in duplicate to tobacco from leaves of the greenhouse plants and from tips of sprouts of cellar plants, the sprouts ranging in length from 3 to 27 inches. The results were as follows:

Green Potato Leaves to Tobacco		Tips of Etiolated Sprouts to Tobacco	
Spot-necrosis	13	Spot-necrosis	0
Healthy-potato	7	Healthy-potato	20

From 8 of the green plants from 10 tubers spot-necrosis was obtained 13 times and healthy-potato 7 times. From the green plants from 2 tubers healthy-potato only was obtained. Only healthy-potato developt in the tobacco plants inoculated from the etiolated sprouts. When inoculations were made from different parts of an etiolated shoot of one of these tubers, the tip portion resulted in healthy-potato, while inoculations from the remainder of the 16-inch shoot, cut into 7 pieces, pro-

duced spot-necrosis in each tobacco plant inoculated. A sprout which had had its tip removed developt a lateral shoot 12 inches long. This was cut into 6 pieces and a tobacco plant inoculated from each. All developt healthy-potato. The parent 8-inch shoot, cut into 4 pieces and each used to inoculate a tobacco plant, caused spot-necrosis in each. These results suggest a segregation of the viruses in the etiolated potato sprouts, following rapid growth and branching, and may perhaps result in a means by which some viruses may be eliminated from affected potatoes.

It is also possible, by dilution of the extracted juice, to transfer the healthy-potato virus alone from spot-necrosis tobacco plants. The undiluted juice and a 1 to 9 dilution with water produced spot-necrosis. All higher dilutions of the same juice up to 1 to 2560 produced only the healthy-potato disease in tobacco or no symptoms at all. The same type of results has been obtained in another way. Transfers of veinbanding to jimson weed (*Datura stramonium*) have resulted in no symptoms whereas transfers of the healthy-potato virus and spot-necrosis have developt mottling. Transfers to tobacco from the veinbanding jimson weeds produced no symptoms, and only healthy-potato symptoms resulted from those inoculated with healthy-potato and spot-necrosis. These results seem to indicate that a separation may be effected in this way also, altho the use of jimson as a certain means of separation needs confirmation.

The methods just mentioned have resulted in the apparent loss of the veinbanding virus from the virus complex. The following method appears to be effective in dropping out the healthy-potato virus from the complex. There is considerable evidence that the healthy-potato virus causes infection less certainly in partially nitrogen-starved plants than in vigorously growing young plants. Therefore Turkish tobacco plants, about 16 inches tall, on which the lower leaves were dying from nitrogen starvation, were inoculated in the lowest green leaves with the spot-necrosis virus in tobacco from interveinal mosaic of Cobbler, rugose mosaic of Green Mountain, and from two

etiolated Cobbler shoots from two tubers affected with rugose mosaic. The plants were then nitrated and brought into a state of vigorous growth. In each of 8 plants so treated only veinbanding symptoms developt and transfers and subtransfers from these to young, vigorous plants resulted in typical veinbanding symptoms only. These experiments prove that the veinbanding virus is present in the spot-necrosis virus complex from interveinal mosaic of Maine Irish Cobbler, rugose mosaic of Maine Green Mountain and mosaic of Kentucky Irish Cobbler potatoes.

The severity of the vein-necrosis symptom of spot-necrosis produced on young, vigorously growing tobacco plants, varies somewhat with the source of the viruses used. Inoculations from Maine interveinal mosaic Cobbler, from a mixture of the healthy-potato virus from Maine interveinal mosaic Cobbler (from a transfer in which only this virus passed) with veinbanding, and from a mixture of the healthy-potato virus (a virulent strain) from a Kentucky Cobbler with veinbanding, each produced an identical severe disease in tobacco as represented in Plate 3, B. It was characterized by severe necrosis of the veins or of the tissue along the veins of the leaves which developt vein chlorosis. In contrast, inoculations from rugose mosaic of Maine Green Mountain and from a mixture of Maine Green Mountain healthy-potato virus with veinbanding, produced a disease in which vein-necrosis was almost absent (Plate 3, A). The virus mixture recently transferred from Kentucky Irish Cobbler produced a disease perhaps slightly milder than that from the Maine Cobbler. Later symptoms of the severe and the milder diseases were about identical. The results of these comparative inoculations, using viruses and virus combinations from various sources, seem to indicate that the degree of necrosis, in the early stages of spot-necrosis, depends on the virulence of the symptoms produced by the healthy-potato virus used. Virulence of the healthy-potato virus seems to depend upon its origin or upon the length of its sojourn in tobacco.

RUGOSE MOSAIC OF POTATOES

Irish Cobbler potatoes grown on the Experiment Station farm, Lexington, often have a mosaic disease. The leaves of affected plants are mildly mottled and slightly distorted. The amount of mottling and degree of distortion appear to vary somewhat. The mottling symptoms develop in the field, and in the greenhouse at a temperature as high as 85° F. The lower leaves of plants grown in the greenhouse gradually become necrotic, die, and drop off, as in rugose mosaic of Green Mountain potatoes, but more slowly. The disease appears very similar to, if not identical with, interveinal mosaic of Irish Cobbler.*

Transfers from mottled Irish Cobbler potatoes to tobacco quite regularly produce spot-necrosis in small rapidly growing Turkish tobacco plants. Thus far spot-necrosis has been obtained over 70 times from mottled Irish Cobbler potatoes. Spot-necrosis of a milder form is obtained from Maine rugose mosaic Green Mountain potatoes. Spot-necrosis, which may be identical with the Kentucky Cobbler spot-necrosis, is also obtained from the Maine interveinal mosaic Cobbler potatoes.

A mosaic of Cobbler potatoes closely resembling rugose mosaic of Green Mountains has been produced by inoculating apparently healthy young Cobbler plants a few inches high with the veinbanding virus or a combination of it with the healthy-potato virus. In each case a plant was grown from a half of the same tuber as a check. The few well-developt leaves present at the time of inoculation usually became necrotic and died, and mottling developt in the growing point leaves. A severe necrotic disease has been produced by inoculating apparently healthy Cobbler plants of a larger size with the veinbanding virus, the disease usually resulting in the death of the inoculated plants. Plants which had nearly completed their growth before inoculation developt mosaic in the growing point and gradually lost most of their leaves, but were not killed so rapidly as the medium sized plants (Table 2).

*Tubers of rugose mosaic, leaf rolling mosaic, crinkle mosaic, and mild mosaic, Green Mountain, and interveinal mosaic Irish Cobblers were furnished by Reiner Bone, Maine Agr. Expt. Sta., to whom the writers are indebted. All references to Maine potatoes in this paper refer to tubers from this source.

Table 2. Inoculations to and from Cobbler potatoes with veinbanding and veinbanding plus healthy-potato viruses.

Source of Inoculum	Plants Inoculated	Results
Potato 5479 1-2, app. healthy	Tobacco 5583-4	Healthy-potato
Tobacco 5457, veinbanding	Potato 5479 1, 18 in. high (see above)	Lower leaves necrotic spots, dropped, growing point mottled
Tobacco 5473, veinbanding and healthy-potato	Potato 5479 2 (see above)	As above
Potato 5479 1 after inocluation (see above)	Tobacco 5857	Spot-necrosis
Potato 5479 2 after inocluation	Tobacco 5858	Spot-necrosis
Potato 5483 1-2 app. healthy	Tobacco 5589-90	2 healthy-potato
Tobacco 5457 veinbanding	Potato 5483 1	Leaves chlorotic and necrotic, mottled, died prematurely
Tobacco 5457 veinbanding, and Tobacco 5473 healthy-potato	Potato 5483 2	As above
Potato 5484 1-2 app. healthy	Tobacco 5591-2	2 healthy-potato
Tobacco 5457 veinbanding	Potato 5484 1 (see above)	Leaves chlorotic, necrotic, plants died prematurely
Tobacco 5457 veinbanding, and Tobacco 5473 healthy-potato	Potato 5484 2 (see above)	As above
Tobacco 5457 veinbanding, and Tobacco 5473 healthy-potato	Potato 5620 1 app. healthy, 4 in. high	3 lower leaves died, growing point rugose, mottled
Potato 5620 1 (see above)	Tobacco 5862 1-2	2 spot-necrosis
Potato 5620 2 (see above)	Tobacco 5863 1-2	2 healthy-potato
Sdlg. potato 5501 veinbanding plus healthy-potato	Potato 5621 1 app. healthy, 4 in. high	3 lower leaves died, growing point mottled
	Potato 5621 2 from same tuber as 5621 1	No symptoms
Potato 5621 1 (see above)	Tobacco 5860 1-2	2 spot-necrosis
Potato 5621 2 (see above)	Tobacco 5861 1-2	2 healthy-potato

When seedling potatoes were used in place of Cobbler potatoes comparable results were obtained (Table 3). Seedling potatoes inoculated with the healthy-potato virus showed faint symptoms as previously described. Plants with these symptoms when inoculated with the veinbanding virus, developt severe chlorosis in which the faint healthy-potato virus symptoms were exaggerated, presenting an appearance very similar to the

typical veinbanding symptoms on Burley tobacco. This was followed by stem and petiole streak, mottling of the growing point, and finally death of the plant (Plate 5, B).

Second tuber generation plants, inoculated with the two viruses in the previous generation after the tubers were well formed, developt rugose mosaic with some streaking, in one case sufficient to kill the young plant (Plate 5, A). The disease was identical with that produced in a similar set of plants inoculated the previous generation with spot-necrosis obtained originally from a rugose mosaic potato. In one instance a seedling potato inoculated from a tobacco plant affected with spot-necrosis (from a mosaic Cobbler potato) developt plants the following generation which were identical with seedlings inoculated with the veinbanding virus alone; that is, faint mottling, rugoseness, and nearly normal color. Transfers from these to small tobacco plants resulted in veinbanding only. In this instance, the healthy-potato virus had been lost in passage to the potato seedling. In one instance, seedling potatoes inoculated the previous generation with the veinbanding virus were inoculated with the healthy-potato virus. A severe disease developt in the growing points of the plants, with chlorosis, slight streaking, leaf necrosis, and gradual death of the plants from the top down, in contrast with the symptoms developt when inoculation was in the reverse order, where death occurred first in the lower leaves.

Table 3. Spot-necrosis, and veinbanding plus healthy-potato inoculations to and from seedling potatoes.

Source of Inoculum	Plants Inoculated	Results
Potato 2273, spot-necrosis	Tobacco 2569-70	2 spot-necrosis
Potato 3757, spot-necrosis	Tobacco 3823	Spot-necrosis
Potato 3757, spot-necrosis (crushed tuber)	Tobacco 4083-4	2 spot-necrosis
	Potato 4384, 2nd generation of 2273	Rugose mosaic, necrotic spots and lines on leaves
Potato 4384 (see above)	Tobacco 4419-20	
Potato 4384 (see above)	Tobacco 4483-6	3 spot-necros, 1 veinbanding
Tobacco 4483 (see above)	Tobacco 4761	Veinbanding

Table 3.—Continued.

Source of Inoculum	Plants Inoculated	Results
Tobacco 4761 (see above)	Tobacco 5239	Veinbanding
Tobacco 4484 (see above)	Tobacco 4762	Veinbanding
Tobacco 4485 (see above)	Tobacco 4763	Veinbanding
Tobacco 4486 (see above)	Tobacco 4764	Veinbanding
Potato 4384 (see above)	Tobacco 4724-5	2 spot-necrosis
Tobacco 4725 (see above	Tobacco 4237-4	Veinbanding
Tobacco 4838, veinbanding and healthy-potato	Potato 5032	Plant nearly mature, no symptoms
Potato 5500, 2nd generation of 5032		Rugose mosaic
Potato 5500	Tobacco 5799-800	Spot-necrosis
Potato 5501, as in 5500		Rugose mosaic and streak
Potato 5501	Tobacco 5535-7	3 spot-necrosis
Potato 5501	Tobacco 5622-3	2 spot-necrosis
Tobacco 4136 2	Potato 4745	Mottled in growing point
	Potato 5497, 2nd generation of 4745	Mottled like veinbanding
Potato 5497 (see above	Tobacco 5628-31	4 veinbanding
Tobacco 4838, veinbanding plus healthy-potato	Potato 5034	No symptoms
	Potato 5502, 2nd generation of 5034	Mottled, rugose
Potato 5502 (see above)	Tobacco 5633-5	3 veinbanding
Tobacco 5473, healthy-potato and tobacco 5457, veinbanding	Potato 5483, 3 plants	General chlorosis, stem streak, leaves died, plants died
Tobacco 5457, veinbanding, and Tobacco 5531, healthy-potato	Potato 5489, 4 plants	As above
Tobacco 5473, healthy-potato	Potato 5507A with veinbanding 3 plants	Growing point leaves chlorotic and necrotic, all died prematurely
Tobacco 5457 veinbanding, and Tobacco 5473, healthy-potato	Potato 5490 1	Necrotic spots, chlorosis, streaks, premature death
Tobacco 5457 veinbanding, and Tobacco 5589, healthy-potato	Potato 5490 2	As above
Tobacco 4137 2 healthy-potato	Potato 4741	No symptoms
Tobacco 5457, veinbanding	Potato 5494, 3 plants from tubers of 4741	Borders of veins dark green, remainder chlorotic, leaf necrosis, streak, premature death

Table 3.—Continued.

Source of Inoculum	Plants Inoculated	Results
Tobacco 5457, veinbanding	Potato 5495 5 healthy-potato previous generation	3 severe necrotic disease
Tobacco 4831, spot-necrosis	Potato 5035-6 nearly mature	No symptoms
	Potato 5498-9, tubers from 5035-6	Rugose and mottled

There is some question as to whether the severe experimental disease, produced by inoculating Cobbler potatoes with the veinbanding virus, occurs in the field. Observations late in the season suggest that a mild form of it does occur, as some plants which were found dying prematurely were chlorotic, were losing their lower leaves, and a few had necrotic streaks on the stem and leaf petioles. Tubers were saved from 21 diseased plants. These were grown in the greenhouse the following spring. Of these 16 developt typical rugose mosaic from which either veinbanding or spot-necrosis was transferred to tobacco. Four were not mottled and from these only healthy-potato or nothing was transmitted to tobacco. One of the latter was from a plant which, in the field, had stem and petiole streak.

The studies with mosaic of Cobbler potatoes show that in the natural disease at least two viruses are concerned, the usual healthy-potato virus and the veinbanding virus; that the disease may be produced by inoculating apparently healthy Cobbler plants of the proper size with either the veinbanding virus or a mixture of it with the healthy-potato virus, or by inoculating them with juice from tobacco plants affected with spot-necrosis. Thus it may be concluded that in the Cobbler variety of potatoes in which the healthy-potato virus appears to be always present the veinbanding virus is the direct cause of one mosaic disease and measures directed toward its control must deal with this virus.

Smith seems to confirm the mixed virus theory of potato mosaic in his comparative studies of insect and prick transmis-

sion of the severe diseases of tobacco to potatoes. He has shown that when the insect-transmitted virus (veinbanding) is transferred to healthy potatoes an intensified mosaic is produced. When the virulent ringspot (spot-necrosis) disease is transmitted by pricking from tobacco to potatoes an intensified mosaic results sometimes indistinguishable from that just mentioned but more often accompanied by necrosis. Transfers to tobacco by the prick method from the former result in symptoms of the insect-transmitted disease (veinbanding); while transfers from the latter produce the virulent disease ringspot (spot-necrosis). These results appear to mean that in the former case the less virulent healthy-potato virus, usually present in potatoes, was carried to tobacco together with the insect-transmitted virus (veinbanding), the combination resulting in what appeared to be the veinbanding type of disease (a common experience in the present studies). In the latter case a virulent strain of the healthy-potato virus was transmitted to and from potatoes together with the veinbanding virus, which resulted in the severe disease in first transfers to tobacco. In the present studies it has been found that if the healthy potato virus is transferred thru tobacco until prominent symptoms are produced, and then transferred to seedling potatoes, the symptoms produced in first transfers from them to tobacco are usually more prominent than the symptoms resulting from first transfers from Cobbler potatoes to tobacco. This suggests that the increased virulence obtained by Smith in transferring ringspot thru tobacco probably was due to an increase in virulence of the healthy-potato virus, the presence of which he did recognize.

MILD MOSAIC AND CRINKLE MOSAIC OF GREEN MOUNTAIN POTATOES

Inoculations from mild mosaic and crinkle mosaic of Maine Green Mountain potatoes to tobacco have given two diseases. One of them is typical of the healthy-potato virus disease obtained from leaf rolling mosaic Green Mountains. The other differs from any previously encountered in these studies. The earliest symptoms of the latter are identical with the healthy-

potato symptoms, but later a mottling develops made up of very small green blotches of different shades which nearly cover the leaf. Then small necrotic spots and short lines may develop in these leaves, giving an appearance somewhat like spot-necrosis. The leaves are not distorted. Later symptoms are typical of healthy-potato. The disease could be mistaken for the healthy-potato disease if plants infected with the latter were not present for direct comparison. While the healthy-potato virus is concerned in this disease it appears certain that another virus is present also which causes the modification of the symptoms of the healthy-potato disease, and is probably the direct cause of mottling in Green Mountains affected with mild and crinkle mosaic. Until this virus can be separated from the healthy-potato virus, its identity with respect to other known virus diseases cannot be determined.

THE PRODUCTION OF OTHER VIRUS DISEASES IN POTATO WITH TOBACCO VIRUSES

If the theory is correct that veinbanding of tobacco, as it occurs on the Experiment Station farm and other places where potatoes have previously been grown, originated in potatoes, then tobacco viruses other than veinbanding (except the true tobacco mosaic) found in the same fields, probably have a similar origin and may be concerned in the potato degeneration disease problem. Only preliminary studies have been made, but these strongly suggest that such is the case.

The true tobacco mosaic viruses are probably not concerned in the Cobbler potato virus problem. Altho they cause local lesions the virus does not appear to spread extensively in the plant and does not appear to enter the tubers either of Cobbler potatoes or of the seedlings which were inoculated. These statements are based on inoculation experiments in which both Irish Cobbler potatoes and seedlings and several quite distinct strains of true tobacco mosaic viruses were used. While occasionally positive results were obtained in transfers from inoculated seedling potatoes to tobacco, the inoculum in these cases was limited in amount and it is possible that some of the original inoculated

tissues may have been included as inoculum. Even tho the parent plant developt extensive leaf and stem necrosis, transfers from tubers and from tuber progeny of innoculated plants have given negative results for the tobacco mosaics. Inoculated Irish Cobbler and seedling potato plants have developed leaf-spots, very similar to alternaria leaf-spots, and necrotic streaks on petioles and stem. Second generation seedling and Cobbler potatoes failed to show symptoms of mosaic.

The Cucumber Mosaic Viruses. The virus to which cucumber mosaic is commonly attributed has not been given much consideration as a possible cause of a potato disease. Doolittle and Walker (2) were able to produce a mosaic disease in potatoes with the cucumber mosaic virus by inoculating them with the aid of aphids. Johnson (7) showed that cucumber mosaic could be transmitted to Triumph potatoes mechanically, where it caused a mosaic disease, but concluded that while all the virus diseases described in his paper, with the exception of "ring-spot," could be transmitted to potatoes, "it is not likely, however, that these viruses are responsible for any potato diseases in nature."

In the present studies inoculations with three quite distinct strains of the cucumber mosaic virus failed to produce symptoms in seedling potatoes, but symptoms developt in an inoculated Cobbler potato which differ from any produced by the other viruses studied. So far, however, positive proof thru transfer back to tobacco has not been obtained. On one occasion cucumber mosaic was transferred from a naturally infected potato sprout to a Turkish tobacco plant. If the cucumber viruses can be transmitted to potatoes experimentally by aphids, infection may also occur in nature. If this is the case, potatoes may have been the chief agent by which the cucumber mosaics have been distributed thruout the vegetable-growing sections of this country. Observations indicate that the cucumber mosaic virus is more prevalent in tobacco in areas where potatoes are frequently grown than in other fields (5).

From specimens of tobacco affected with a virus disease, sent to the writers from Minnesota by H. H. Thornberry, a

severe strain of cucumber mosaic was obtained which was found to be mixed with the veinbanding virus.† As Smith demonstrated, *Myzus persicae* can transmit veinbanding from potatoes to tobacco. As it is known that the same insect transmits the cucumber mosaic virus it is possible that both veinbanding and the cucumber mosaic had a single origin in potatoes and were transmitted together either from it or from an intermediate host.

Tobacco ringspot. In his studies of tobacco ringspot, Priode (10) was unable to demonstrate that the potato was a host of this virus. During the course of the present studies an Irish Cobbler potato plant was found by the junior writer which showed peculiar yellowing of the foliage corresponding closely to Aucuba mosaic (11). Transfers from this plant and from two subsequent tuber generations to tobacco demonstrated that it carried the tobacco ringspot virus. In these transfers not only tobacco ringspot symptoms develop, but also mild symptoms of the healthy-potato virus. Tobacco ringspot seems to be a rare disease of Cobbler potatoes but it occurs naturally. Mechanical transfers from tobacco to either seedling potatoes or to Irish Cobblers have not resulted in infection.

The etch viruses. At least three virus diseases of tobacco all similar but differing in severity and maintaining the difference after many transfers thru tobacco plants in the greenhouse, are under study. Tobacco plants affected with the etch virus are quite abundant on the Experiment Station farm after the tobacco has attained some growth and are regularly present in other fields where veinbanding is prevalent (5). The early symptoms in the field are sometimes much like those of veinbanding and occasionally lead to confusion in diagnosis. Later symptoms are distinct. The distribution of the two types of disease and their rate of spread correspond rather closely and suggest a common source and means of dissemination.* Preliminary studies indicate clearly that the three viruses, etch,

†This was previously reported as mixed with the healthy-potato virus. Ky. Exp. Sta. Ann. Rpt. 1928, p. 14.

*In 1930 veinbanding was as prevalent as usual in tobacco on the Experiment Station farm but the etch diseases were comparatively rare thus raising a question as to the correctness of this statement.

etch +, and severe etch, can each be transferred to potatoes where they produce a disease of the rugose type somewhat similar to that produced by veinbanding, except that there is

Table 4. Etch virus inoculations, from seedling potatoes previously inoculated, to Turkish tobacco.

Source of Inoculum	Plants Inoculated	Results
Potato 1657, etch	Tobacco 1916	Etch
Potato 1658, etch +	Tobacco 1917	———
Potato 1714, severe etch	Tobacco 1919	———
Potato 2267, etch	Tobacco 2557-8	———
Potato 2271, severe etch	Tobacco 2565-6	2 severe etch
Potato 3656, severe etch	Tobacco 3808-10	3 severe etch
Potato 3657, etch +	Tobacco 3811-3	3 etch +
Potato 3754, etch	Tobacco 3819	Etch
Potato 3759, etch (Ga.)	Tobacco 3825	Etch
Potato 3656, severe etch, crushed tuber	Tobacco 4034-6	———
Potato 3657, etch +	Tobacco 4037-9	3 etch +
Potato 3754, etch	Tobacco 4077-8	———
Potato 3759, etch (Ga.)	Tobacco 4088-9	———
.....	Potato 4331, etch, 2nd generation	Mottled, rugose, and slight necrosis
.....	Potato 4332, etch + 2nd generation	Rugose, slightly mottled
.....	Potato 4335, severe etch, 2nd generation	Mottled, rugose
Potato 4331, etch, 2nd generation	Tobacco 4366-7	———
Potato 4335, severe etch, 2nd generation	Tobacco 4374-5	———
Potato 4331, etch, 2nd generation	Tobacco 4477-8	2 etch
Potato 4335, severe etch, 2nd generation	Tobacco 4481-2	2 severe etch
Potato 4431, etch, 2nd generation	Tobacco 4710-11	2 etch
Potato 4335, severe etch, 2nd generation	Tobacco 4714-15	1 severe etch
Potato 5518, etch, 3rd generation	Tobacco 5564-6	3 etch
Potato 5519, severe etch, 3rd generation	Tobacco 5561-3	3 severe etch
Potato 5518, etch, 3rd generation	Tobacco 5596	Etch
Potato 5519, severe etch, 3rd generation	Tobacco 5600-2	2 severe etch
Potato 5508A, etch, 3rd generation	Tobacco 5607-8	2 etch

usually more leaf distortion and larger but fewer chlorotic areas in the etch diseases.

Transfers to tobacco from second and third tuber generation seedling potato plants inoculated the first generation with these viruses have given positive results (Table 4). These results, together with the fact that the etch viruses are more commonly found in tobacco where potatoes have been grown, suggest that these viruses are the cause of certain degeneration diseases of potatoes and that potatoes were the source from which the native vegetation has become infected.

DISCUSSION

It has been demonstrated in the present study that in a mosaic disease of Irish Cobbler potatoes and in the spot-necrosis disease, caused in tobacco by transfers from these plants, a mixture of the healthy-potato virus and the veinbanding virus is concerned. As veinbanding is a common disease of tobacco where potatoes have been grown, even many years previously, and as the veinbanding virus is evidently present in certain mosaic potatoes, the suggestion is made that other virus diseases of tobacco commonly found in such fields (other than the true tobacco mosaics) also have their origin in potatoes and are directly concerned in the potato virus problem. In confirmation of this theory, mosaic of a rugose type was produced in seedling potatoes by inoculating them with members of the etch group of viruses.

As the healthy-potato virus is almost universally present in apparently healthy potatoes, it seems fair to assume that in a study of the potato virus diseases, mixed viruses always are concerned, as pointed out by J. Johnson (8). One of the significant findings of the recent studies is that certain viruses have very wide host ranges. Therefore, is there any reason to believe that, in the final analysis, the viruses which are the cause of potato degeneration diseases will not likewise be found to have a wider host range than the potato plant itself? And is it not reasonable to suppose that the most rapid progress will ultimately be made in this complicated problem by concentrating effort on

the transfer of the viruses to other hosts, or to seedling potatoes, where they may be studied in the pure state? Because of their mixed state in potato varieties and the ease with which the healthy-potato virus transfers to tobacco by mechanical means, this seems to present difficulties. Smith's studies (13) of insect transfer of the mosaic disease of potatoes to tobacco suggest that the aphid, *Myzus persicae*, may be used as a means of separating any virus, which it will transmit, from the healthy potato virus. By this method it should be possible to transfer, not only the veinbanding virus, but the cucumber mosaic viruses, leaf roll, probably the etch viruses, and perhaps other viruses of potatoes, to virus-free seedlings, or perhaps to other hosts where they may be studied in a pure state. This is essential to a proper study of these diseases, as little further progress can be expected in exact identification of potato virus diseases until they can be studied under conditions where clear-cut symptoms can be used as the basis of final diagnosis. It is not likely that chemical or physical studies of the viruses will soon reach a point where they can be used to distinguish the individual virus diseases, especially when mixtures are concerned. They may be of use in identifying groups of viruses, such as the true tobacco mosaics, the cucumber mosaics, or the etch viruses, but it is not likely that they will be of value within these groups. Indeed it is probable that symptoms will continue to be the easiest and surest method of diagnosis after methods have been devised for obtaining the viruses in pure culture in a host in which recognizable symptoms are produced.

Likewise rapid progress in complete control of the potato viruses cannot be expected until more knowledge is obtained of the identity of the individual viruses concerned and their weed-host range. Weed eradication, together with breeding work having as its object the production of desirable seedling potato varieties free from any virus, seems to promise a solution of the potato virus problem.

In breeding potato varieties serious consideration should be given to the possibility of maintaining the new strains free from the healthy-potato virus. The evidence so far obtained suggests

that this virus is rarely carried to weeds, or if it is, that it is rarely, if ever, carried to tobacco from the weeds. Therefore it is not likely that it will be carried from weeds to potatoes or from potatoes to potatoes by insects except by purely mechanical means such as by biting insects, or in handling by man. There is the possibility that it may be transferred to tubers of seedlings by means of the cutting knife and one introduced it would, of course, remain in the progeny of infected tubers indefinitely. This means of transfer has not been established. The possibility of its occurrence might be eliminated by maintaining a stock propagated entirely from whole tubers, or from tubers cut under conditions which would eliminate the possibility of infection from the common varieties. It would then be preferable to grow the seedling stock away from potatoes known to carry this virus.

While it has not been demonstrated that the healthy-potato virus alone is detrimental to potatoes, it is probable that this is the case in varieties, such as Bliss Triumph, in which symptoms are recognizable. There is also injury, resulting from virus mixtures, which would not occur so frequently were the variety free from this now apparently universal virus.

If the evidence obtained with tobacco, which appears to act as an indicator of the distribution of certain potato viruses in native vegetation, is found to be as significant as now appears, then there are many fields in which virus-free potatoes might be grown with reasonable assurance that they would remain free from virus infection. On the contrary, the same variety grown in areas where potatoes have long been grown may be expected to become contaminated with viruses, even tho kept entirely isolated from present varieties, unless close attention is given to the eradication of weeds in, and in the vicinity of, the field where the potatoes are grown.

SUMMARY

1. A disease of tobacco characterized by dark green bands along the veins of the older leaves is found in tobacco fields where potatoes have previously been grown. This disease is called veinbanding.

2. Irish Cobbler potato plants, whether apparently healthy or diseased, seem always to carry a virus called the healthy-potato virus. This virus causes a disease in tobacco characterized by necrotic and chlorotic ring and line patterns.

3. Transfers from mosaic of Irish Cobbler potatoes to tobacco produce a disease known as spot-necrosis, the later symptoms of which are often predominently those of veinbanding. Spot-necrosis is also obtained from rugose mosaic of Green Mountain and interveinal mosaic of Irish Cobbler potatoes. Transfers from rugose mosaic potatoes or from spot-necrosis tobacco plants to partially nitrogen-starved tobacco plants frequently produce only veinbanding.

4. A mixture of the veinbanding virus and the healthy-potato virus when inoculated into tobacco plants produces spot-necrosis identical with that produced by inoculating tobacco with juice from rugose mosaic potato plants.

5. When inoculated into virus-free seedling potatoes the veinbanding virus causes a disease. When seedling potatoes, previously inoculated with the healthy-potato virus, are inoculated with veinbanding, rugose mosaic results. When the veinbanding virus is inoculated into apparently healthy Irish Cobbler potatoes a disease similar to rugose mosaic results.

6. The cucumber mosaic virus has been shown by others to cause a mosaic in potatoes. The suggestion is here made that potatoes have acted as agents in disseminating this virus and that the various strains of it, of which there are at least three, are causes of potato degenerative diseases.

7. Ringspot of tobacco is distinct from the healthy-potato virus which has as one symptom necrotic ring and line patterns. Tobacco ringspot may infect potatoes, causing a striking disease similar to Aucuba mosaic as prescribed by Quanjer.

8. The etch viruses, of which there appear to be at least three distinct strains, may be transferred to potatoes where they produce a rugose type of mosaic somewhat similar to that caused by veinbanding. As the etch diseases of tobacco are found more frequently where potatoes previously have been grown and where veinbanding is present, and as they cause definite diseases of potatoes, the suggestion is made that they are causes of potato degeneration diseases.

9. As the only apparent source of infection of tobacco plants in the field with veinbanding, the etch virsuses, and cucumber mosaics,

is from the native vegetation, it seems evident that weeds may also play an important role in the potato virus problem. The suggestion is made that tobacco might be used in sections where potatoes are grown, in a study of at least a portion of the potato virus population of the local vegetation.

10. Two virus diseases have been transferred from mild mosaic Green Mountain potatoes to tobacco. One of these is the healthy-potato disease and the other is apparently a mixture of this with another virus, the identity of which has not been determined.

11. Experimental results of others may be interpreted as proving that the aphid, *Myzus persicae*, rarely if ever transmits the healthy-potato virus, while it regularly transmits the veinbanding virus from virus mixtures. It is suggested that this insect might be a valuable aid in the study of potato viruses in that it could be used to separate veinbanding, the cucumber mosaics, probably the etch viruses, leaf-roll and perhaps other viruses from mixtures with the healthy-potato virus, and thus give an opportunity of studying them in a pure state in seedling potatoes or in other hosts.

12. A proper recognition of the importance of weed hosts in the potato virus problem, together with the development of potato seedlings having the desired qualities and free from viruses, may lead eventually to a practical solution of the potato virus problem.

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Plate 1. A. Early symptoms of the healthy-potato virus on a small, vigorously growing Turkish tobacco plant (5591). The dark bands along the veins on the leaf to the left are often characteristic of first transfers from potatoes to Turkish tobacco plants making rapid growth. This symptom should not be confused with veinbanding. B. Necrotic rings of the healthy-potato virus, originally from Cobbler potato, on rubbed leaves of Turkish tobacco (5918). C. Chlorotic ring and curved line patterns on an older leaf of a Turkish tobacco plant (5473) inoculated with a virulent strain of the healthy-potato virus. The patterns sometimes become necrotic. D. Necrotic rings and spots of tobacco ringspot on rubbed leaves of a Turkish tobacco plant (5907). The plant from which inoculum was obtained was raised from a ringspot plant and was infected naturally by seed-borne virus. The rings and spots are typical of the early symptoms of tobacco ringspot and are distinctly different from those produced by the healthy-potato virus.

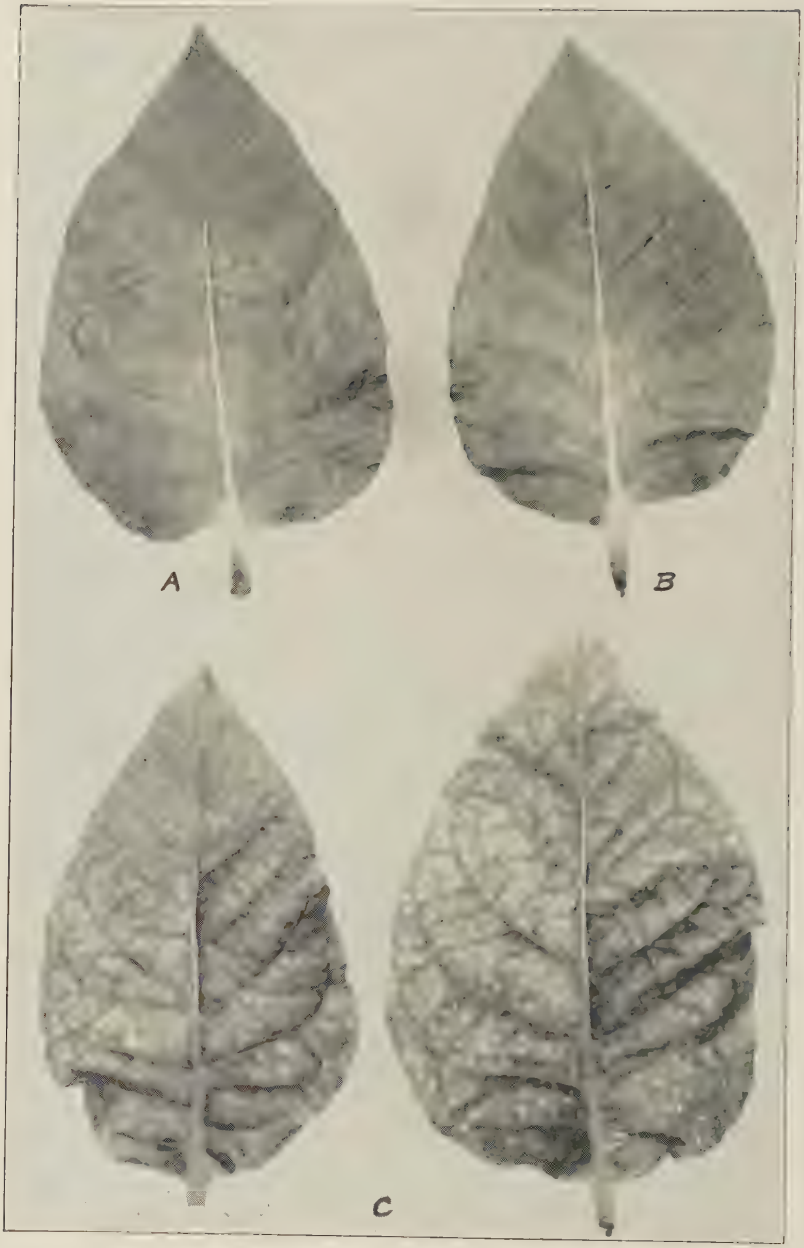

Plate 2. A, B. Typical veinbanding symptoms in Turkish tobacco produced by inoculating the lower leaves of partially nitrogen-starved plants 12 inches tall with the mixed virus from a spot-necrosis tobacco plant. A. (6180) Virus originally from rugose mosaic Green Mountain potatoes, and B. (6182) from an etiolated Irish Cobbler sprout. C. Spot-necrosis in Turkish tobacco (6185 A and B) showing necrotic spotting and veinbanding. The mixed virus was obtained from an etiolated Irish Cobbler sprout and passed thru one tobacco plant before inoculating these plants.

Plate 3. A. Early symptoms of spot-necrosis of Turkish tobacco (6197A) produced by inoculation with a mixture of the healthy-potato virus, originally from a leaf rolling mosaic Green Mountain potato, and veinbanding virus obtained originally from Burley tobacco. The symptoms are nearly identical with the early symptoms of veinbanding, and are typical of the symptoms produced in Turkish tobacco when inoculated directly from rugose mosaic Green Mountains. B. Early symptoms of spot-necrosis of Turkish tobacco (6199A) produced by inoculation with a mixture of the healthy-potato virus originally from Irish Cobbler, but carried thru many Turkish tobacco plants (see Plate 2, C.), and veinbanding as in A. The symptoms are typical of those produced by inoculating tobacco directly from Maine interveinal mosaic Irish Cobblers, and are only slightly more severe than symptoms resulting from inoculations directly from Kentucky mosaic Cobblers.

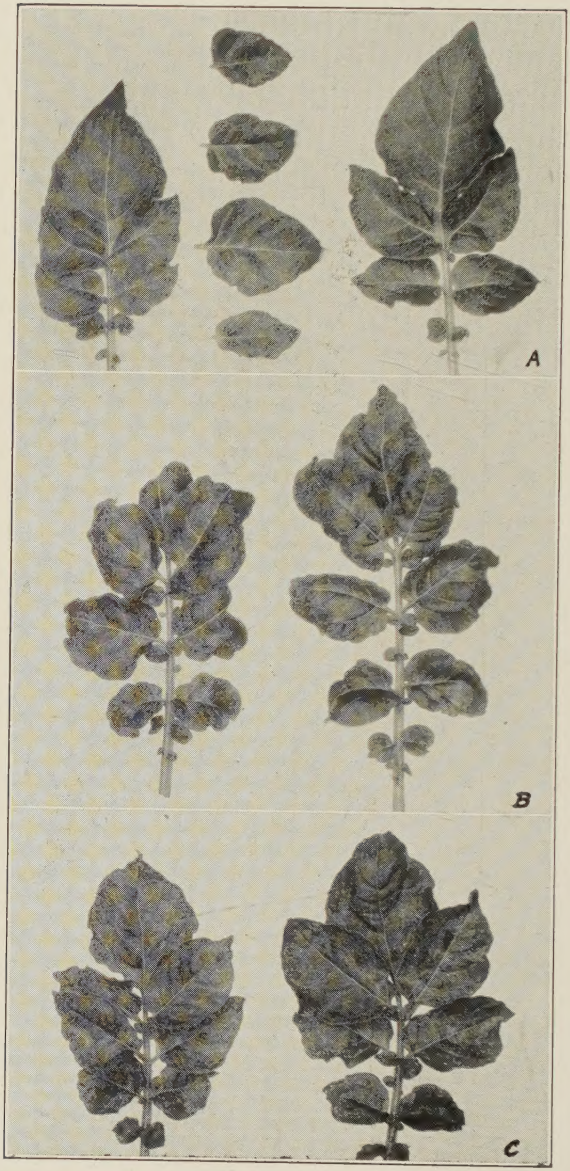

Plate 4. A. Seedling potato (5516) inoculated the previous tuber generation with the veinbanding virus. B. Seedling potato (5501) inoculated the previous tuber generation with a mixture of the healthy-potato virus and veinbanding. C. Seedling potato (5498) inoculated the previous tuber generation with the spot necrosis virus of tobacco (healthy-potato and veinbanding) obtained originally from mosaic Cobbler potato.

Plate 5. A. Seedling potato plants (5501) inoculated the previous tuber generation with a mixture of the healthy-potato virus and veinbanding when the tubers were nearly mature. The leaves are mottled (Plate 4, B.) and necrotic streaks are present on both stalks. The smaller one is nearly dead. B. Seedling potato plants (5488) inoculated the current generation with a mixture of the healthy-potato virus and veinbanding (right) and uninoculated (left). Leaf necrosis petiole and stalk streak, and finally death of the inoculated plants resulted.